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THE BIOPSYCHOLOGY OF AUTISTIC AND NORMAL CHILDREN

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A b s t r a c t. A three-year-study was made of autistic and normal children. Behaviour was studied using ethological methods. Endocrine physiology was studied by measuring catecholamine excretion rates. Clear differences in behaviour were found between the two groups. Endocrine differences did not correlate with behaviour differences at the group level, but did so at the individual level. Findings suggest that behaviour functions to stabilise physiological systems within normal tolerance limits. The implications of this approach for the understanding of the biopsychology of stress are discussed.

Key words: biopsychology, behaviour, endocrine differences, catecholamine excretion rate, normal children, autistic children.

Introduction

In this necessarily short paper the author wants to do three things. First to describe some of the studies carried out by his department in the field of catecholamines and behaviour. Second to focus on one study in which a co-worker, H. Helevuo and he were especially involved concerning normal and autistic children. And third to try and sketch a theoretical model based on the research they have done to show how behaviour may relate to underlying physiological processes.

But first, the author should like to introduce the subject of catecholamines and behaviour as a whole. Catecholamines, notably adrenaline* and noradrenaline* but also their metabolites, can be studied in the serum or the urine, and additionally noradrenaline can be studied in the CNS where it is a plentiful neurotransmitter. All our studies have been on urinary catecholamines. There are good reasons for this. We have not wanted in particular to investigate CNS (neuro-) physiology in relation to behaviour. Such studies are extensively pursued elsewhere and present many problems of their own. As regards the question: "blood or urine?", we are seeking for a measure of *secretion* rates (from the adrenal medulla) in our studies, but although this would seem to favour taking measurements from the bloodstream we have not in fact done so, preferring urinary *excretion* rates for a number of reasons. Primarily, especially with children, it is upsetting for them to be subject to blood testing proce-

*The term adrenaline is synonymous with epinephrine, noradrenaline is synonymous with norepinephrine etc.

dures, let alone to having an indwelling catheter or anything like that. Second, it is not in fact permitted to take blood samples from children for non-medical reasons and we could be technically committing an assault on children if we did so. Third, we wanted the situations under study to be as natural as possible, because our interests are mainly in the *normal* physiology of behaviour. The reason for including samples of autistic children in the work was to try and shed light on the normal ones by including an abnormal group for comparison. The question does arise, however, whether urinary catecholamine levels are comparable to blood levels, or how the two are related. In theory, it could be argued that the two levels might vary quite differently so let us look at this matter. We can distinguish three possibilities: first that if blood levels are high, urinary levels would be low. Thus it could be argued that if the body's needs for adrenaline are great, there will be a high rate of secretion into the bloodstream, but owing to a high rate of take-up, use and breakdown excreted levels would be low. The opposite could also be argued: that a high secretion rate would be reflected in a high excretion rate. Lastly it could be argued that there can be no clear relation between the two because of the complexity of the metabolic processes involved.

Our studies have been based on the second assumption, which underlies previous work in the field in the USA and in Sweden. But we have not just made the assumption. We have attempted to establish the facts by measuring not just urinary adrenaline and noradrenaline, but also their chief metabolites, metadrenaline, normetadrenaline and vanil-mandelic acid (VMA). We have found that levels of these metabolites co-vary with the levels of the primary catecholamines in the urine, i.e. where one is high all are high, and vice versa. This we have interpreted to mean that a high excreted level does indeed indicate a high secreted level since otherwise we could expect to find a higher or lower relative level of metabolites to primary catecholamines depending on the extent of body take up of the initial secretions. Our findings also indicate that measurements of urinary adrenaline and noradrenaline alone are enough to indicate secretion levels since the measurement of the metabolites does not add extra information about secretion levels (besides being time-consuming and rather difficult).

A second line of evidence indicating that urinary catecholamine levels are an accurate indicator of secretion levels relates to their functional significance in general. The early work of CANNON (1953) in particular indicated that adrenaline was secreted by the adrenal medulla at times of emotional arousal and he suggested that it was a hormone functioning to enrich the content of the blood by liberating into it stored glygogen and other substances useful for the efficient functioning of central body organs and muscular tissue at times of 'fight or flight', e.g. in emergency situations. It thus acts as a back-up system prolonging the immediate effects of the sympathetic nervous system which provides an initial boost and, in fact, activates the adrenal medulla itself via the splanchnic nerve, contracting it to discharge its contents into the adrenal vein.

Because CANNON's hypothesis has received support ever since and been amplified in various ways, adrenaline, and to some extent noradrenaline, too, have often been called 'stress hormones' and it is for this reason that we have focussed on them in our research. There are other 'stress hormones', notably the adrenal cortico-steroids produced by the adrenal cortex, but these

are slower acting and less sensitive measures of emotional experience than adrenaline. Finally, to round off these introductory remarks, we should note that in the last decade or so it has become increasingly possible to make very accurate estimations of the quantity of adrenaline and noradrenaline present in samples, and we have used the most accurate method available at the time of study, namely spectrofluorometry, a technique based on the fluorescent property of adrenaline and noradrenaline in suitably prepared samples coupled with a chart recorder. Full details of the method used can be found in Dr. HELEVUO's thesis (1978), available at the Bodleian Library, Oxford.

Other studies

Brief mention will now be made of other relevant studies made elsewhere, and in our own department.

Elsewhere, catecholamine studies have mainly been made in the USA and Sweden, but there have been some in Britain, too. For the most part, people have been studied in situations where there is a clear element of psychological stress and their catecholamine levels have been compared before, during and after a so-called 'stress' period. For example studies have been made of free-fall parachutists, people undergoing dental treatment, people watching various kinds of films, racing drivers, ordinary drivers, trawlermen working in difficult conditions, children undergoing mathematical tests, train commuters on crowded trains, and sawmill workers in repetitive, noisy working conditions. Such studies all add up to a picture of increased catecholamine output in stressful conditions (see MASON 1968, LEVI 1971).

We should note, however, that while the environmental factors have been well described and the catecholamine levels accurately measured the actual behaviour accompanying the stressful situations has not normally been described in any systematic way. By using the methods of description of ethology we have brought far more accuracy to the behavioural side of the study in our work on children.

Besides the study of children which will be described next, we have at Oxford made a further series of studies, some small-scale, others larger. Each method (small, individual and large, population studies) contributes in different ways, as will be clear later in this paper.

On the individual side we have collected data on a percussionist in a rock band, lecturers in our department delivering lectures and seminars, and students performing at examinations. Longer-term studies have included 24-hour and one 2-week study of individuals, thus giving data on circadian rhythms as well as times of stress. These longer studies also involve a diary of events kept by the subject. In recent studies we have added data on heart rate, respiratory rate and skin resistance to the catecholamine data, using a Medilog ambulatory monitoring device for the heart rate data. Finally, we are currently engaged in a large-scale study of the health and life-style of the adult populations of a number of villages to the north of Oxford, and have collected urine samples from these people and begun to relate their catecholamine levels to aspects of their life-styles such as occupation.

The study of children

This study consisted of observations of two types of children, normal and autistic, to compare their behaviour and see if there were any correlations between their behaviour and their catecholamine excretion rates. The autistic group was included because it has been suggested, notably by the TINBERGENS (1972), RICHER (1976) and others, that they are under stress. Would they, then, show an unduly high level of catecholamines?

We did the study twice over, once on a sample of 10 normal children aged 5—6 years at a primary school, and 4 slightly older autistic children attending a hospital school (Table 1).

Table 1

Age, sex and weight of children in the first sample

Child	Normal or autistic	Sex	Age (months)	Wt (kg)
Anna	normal	F	68	19
Christine	normal	F	68	20
Helen	normal	F	68	23
Laura	normal	F	67	22
Linda	normal	F	65	33
Andrew	normal	M	67	20
Alex	normal	M	66	20
Michael	normal	M	62	18
Peter	normal	M	70	23
Tom	normal	M	63	19
Darrell	autistic	M	118	28
Henry	autistic	M	112	28
Ken	autistic	M	88	19
Sam	autistic	M	93	24

Behaviour was recorded by an observer (H. HELEVUO) in the room with the children, who were observed in a randomised order which nevertheless was adjusted so that each child had the same total observation time. Normals were observed over a total of 6 mornings, autists could only be observed on 5 occasions and these were afternoons. A checksheet system was used, behaviour being recorded in the form of occurrence or non-occurrence of specified *units* of behaviour during the period concerned. The units are shown in Table 2 together with a set of *categories* into which the units were grouped for the sake of later analysis and comparisons. Note the 'Locomotion' categories in this table. These were included because noradrenaline levels in particular are known to vary according to the extent of locomotor activity, and we, therefore, needed this information in order to interpret noradrenaline findings. The other categories are mainly descriptive or motivational, and are based on earlier work by myself and others on children's behaviour.

Regarding the urine collection procedure, bladders were emptied for all children before the observation period and again afterwards. The first time the urine was discarded, the second time it was saved, and aliquots prepared and frozen for subsequent analysis. Finally, a series of overnight (i.e. first

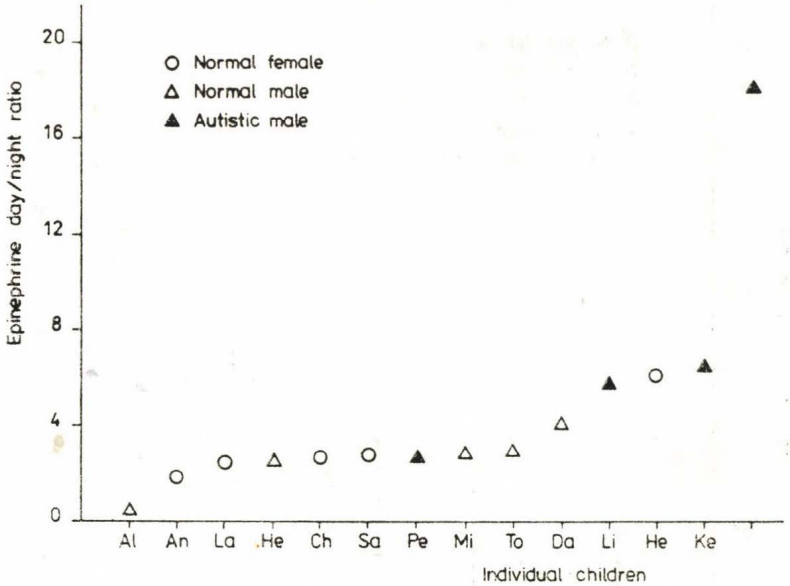

Fig. 1: Ratio of mean daytime epinephrine excretion rates to night-time excretion rates, first sample. Normal mean 2.9, autistic mean 8.3. *t* test, 2.55, $P < 0.05$

urination in the morning) samples was obtained for each child (with parental help) for comparison with the daytime samples.

The results of the first year's work (sample of children just described) were as follows. Taking the catecholamines first, the clearest results were for adrenaline, where there was a significant finding that autists were excreting more adrenaline than normals in relation to overnight levels (Fig. 1).

In fact, autistic children seemed to have unusually low overnight levels. However, the sample size was too small for generalisation, and we realised the need for a larger study to confirm or reject this finding. The adrenaline results are shown in Figure 2.

Regarding behaviour, the clearest difference was, as expected, in solo behaviour (Fig. 3). As the figure shows, the two groups were wholly separate for these kinds of solitary activity. Note that the high levels of solo behaviour indicate that autistic children are not inactive; on the contrary they are doing things but the things they do are not social. It goes without saying that their scores on 'positive' or 'friendly' social behaviour are lower than those of normal children, as Fig. 4 (Initiate Associative) shows. Some individual autists did, however, show occasional outbursts of very aggressive behaviour.

We analysed the relation between behaviour and catecholamines for all the children, normal and autistic, together. This showed a number of correlations, as shown in the Table 3. Most of the correlations arose, as can be seen, when day/night ratios were used rather than daytime levels. Part of the reason for this is doubtless the extent of individual variability in actual levels of catecholamine 'arousal'. As was seen in the overall adrenaline results, intra-individual variance was considerably less than inter-individual variance, i.e. the children showed day-to-day constancy in their catecholamine levels. This

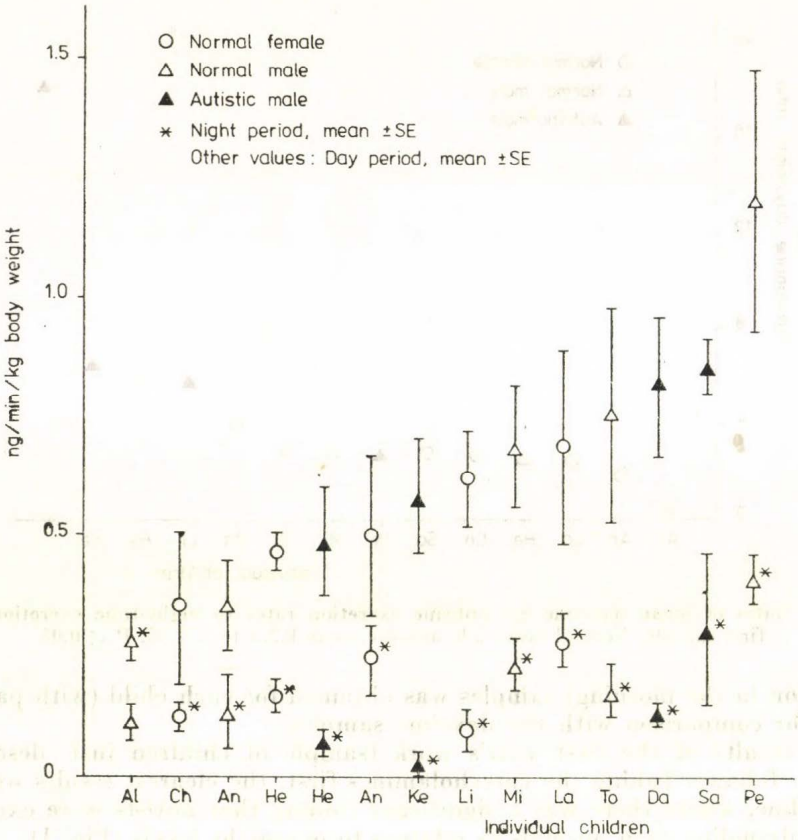

Fig. 2: **Individual variation in epinephrine excretion rates, first sample**

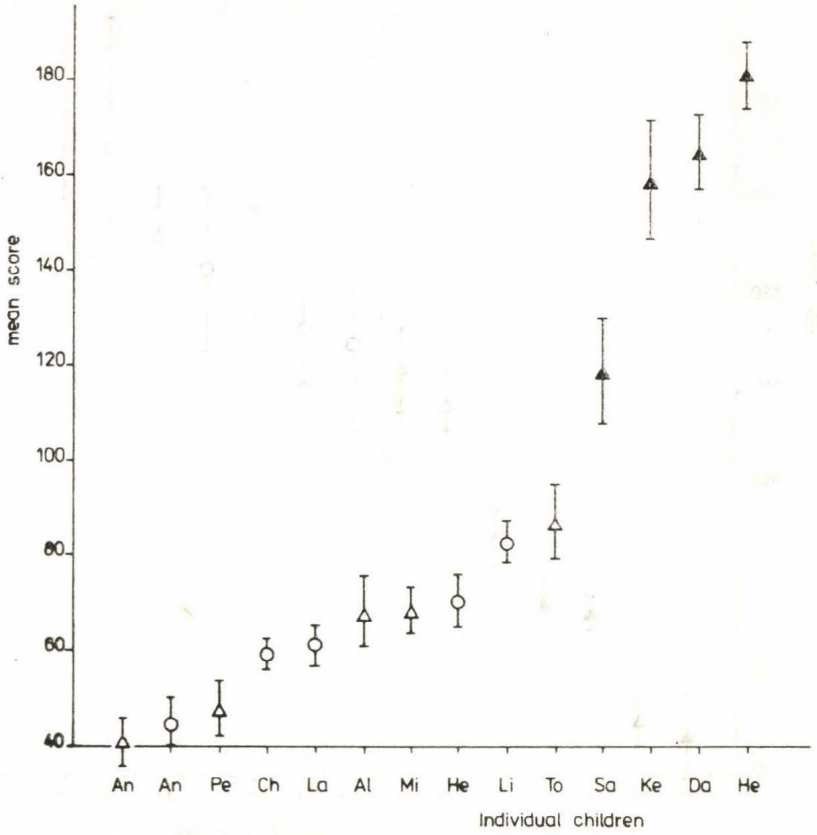

Fig. 3: **Individual variation in solo behaviour, first sample. (For explanation of signs see Fig. 2)**

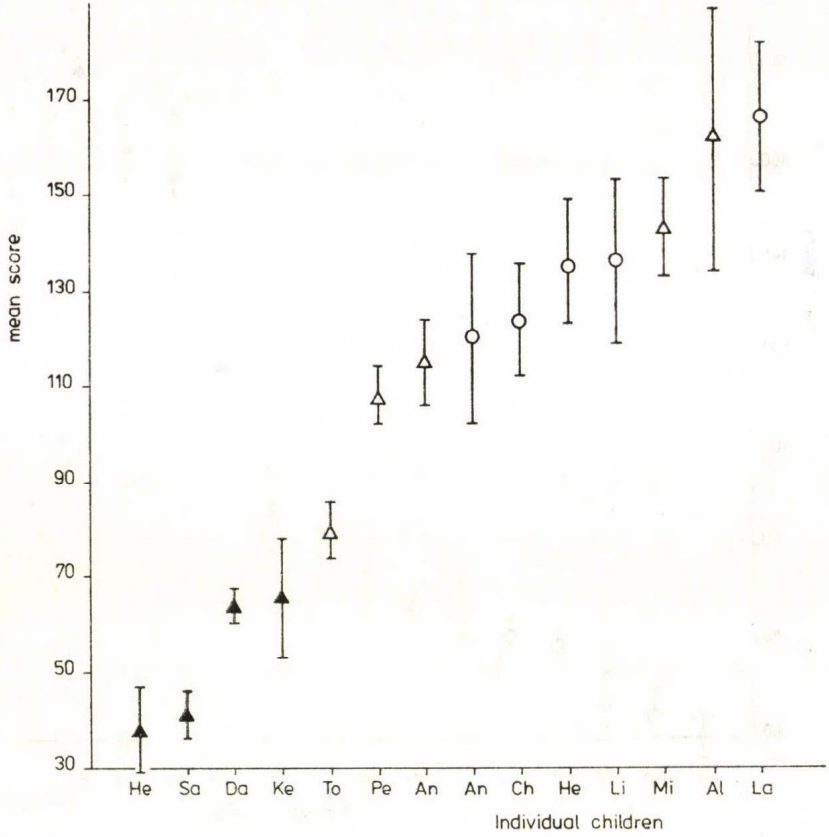

Fig. 4: **Initiate associative behaviour scores, first sample (signs as in Fig. 2)**

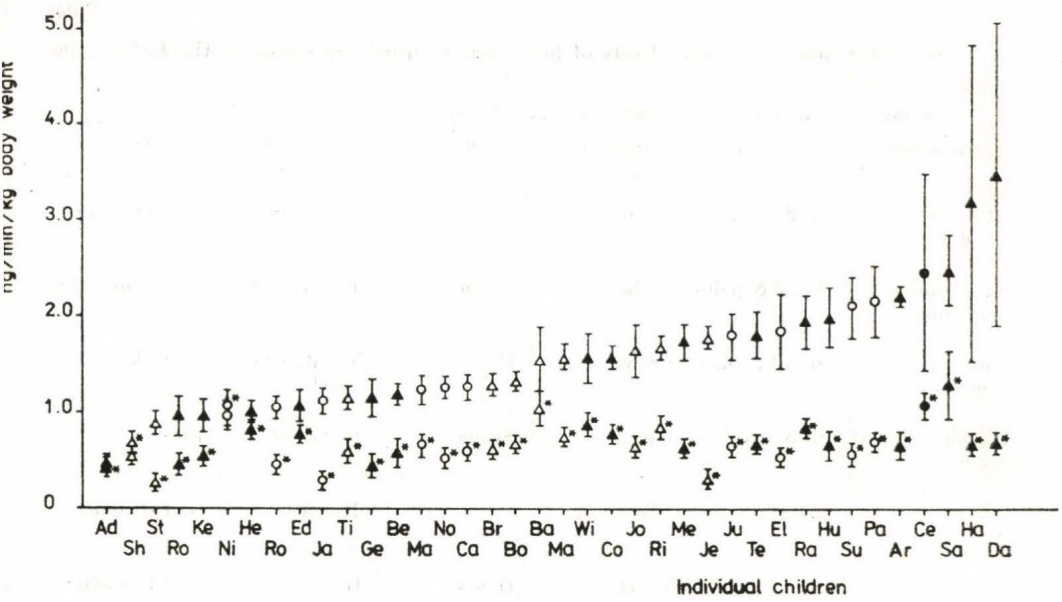

Fig. 5: Individual variation in norepinephrine excretion rates, second sample (signs as in Fig. 2)

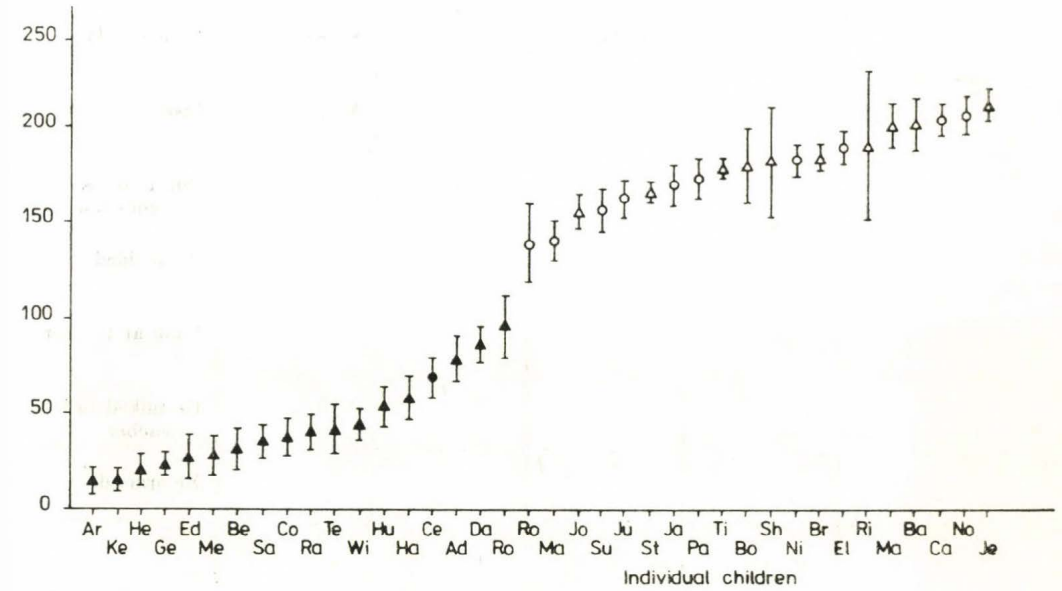

Fig. 6: Individual variation (means ± SE) in Initiative Associative behaviour, second sample (signs as in Fig. 2)

Table

Behaviour catalogue used. —Units of behaviour recorded are shown in the body of the

Locomotion 0 (immobile)	Locomotion 1 (Minor)	Locomotion 2 (Medium)	Locomotion 3 (Major)	Solo behaviour	School-oriented behaviour
Sit doing nothing	Sit & write	Climb	Run	Self groom	Be given task
Stand doing nothing	Stand & paint	Walk	Jump	Talk to self	Be commanded
Crouch doing nothing	Stand & play	Crawl	Hop	Vocalize to self	Do task
Lie doing nothing	Sit & drink	Shrug	Swing	Self display	Play
	Kneel	Place walk	Hang	Mouthe	Go to teacher
		Twist	Dance	Gaze	Talk to teacher
		Balance	Play beat	Look at object	Shcw to teacher
		Roll	Move heavy things	Glance	Comply
		Any Tremor		Stare	Non-comply
				Watch	Listen
					Question/ask permission
					Be scolded
					Look at teacher
					Be talked to by teacher
					Be praised

table. Column heads denote names of categories into which units were grouped

Initiate associative behaviour	Receive associative behaviour	Initiative assertive behaviour	Receive assertive behaviour	Initiate aggressive behaviour	Receive aggressive behaviour
Smile	Be approached	Command	Be commanded	Provoke	Be provoked
Go to	Receive object	Try to take	Be taken from	Hit	Be hit
Give object	Be helped	Akimbo	Be pointed at	Push	Be pushed
Help	Be soothed	Search	Be asserted to	Grab	Be grabbed
Soothe	Be hugged	Point		Wrestle	Be kicked
Hug	Be patted	Demand		Kick	Be bitten
Pat	Be kissed	Take		Bite	Be schratched
Kiss	Receive contact	Assert		Scratch	Be shown tongue
Physical contact	Receive attention			Tongue out	Be banged
Hand in hand	Be shown to			Bang object with object	Be thrown
Seek attention	Be asked company			Tantrum	
Show to X	Be talked to by peer			Rough and tumble	
Ask company	Be looked at			Throw	
Talk to peer	Be talked to by me				
Talk to me					
Look at peer					
Look at me					

Table 3

Correlations between behaviour scores and catecholamine excretion rate; first sample

Behaviour	Catecholamine	r_s	$P<$
High initiate associative	low E d/n*	0.568	0.05
High initiate aggressive	high MN d	0.542	0.02
High solo	high E d/n	0.749	0.01
High receive associative	low E d/n	0.547	0.05
High initiate assertive	low E d/n	0.640	0.05
High total locomotion	high NE d/n	0.644	0.05
High total locomotion	high MN d/n	0.532	0.05
High total locomotion	high VMA d|n	0.552	0.05

* d, day; d/n, day/night.
r_s: correlation coefficient between behaviour score and catecholamine excretion level (Spearman Rank Correlation, $N = 14$; 10 normals, 4 autists)

confirms earlier Swedish findings, and the work of MONTAGNER et al. (1978) in corticosteroid levels.

Owing to the small sample size, as stated, we repeated the study during the second year on a larger number of children. There were 20 normal and 18 autistic children. The normal children were in a different Oxford primary school. The autists were made up of the 4 from the first sample plus 6 more from that Hospital school plus a further 8 from an autistic school in Ealing. Data were collected on 4 consecutive mornings, together with overnight samples, for all children (Table 4).

Results of the larger second study were in some respects interesting and in others disappointing.

Figure 5 shows the catecholamine results for the second sample, showing noradrenaline on this occasion, mainly to illustrate once again that the extent of intra-individual variation is considerably less than that of inter-individual variation, i.e. children are fairly consistent in their individual catecholamine output levels from day to day, but vary considerably from one another. Autistic children and normals did not differ consistently for any of the catecholamines measured, either with regard to daytime levels or day: night ratios.

In behaviour the same differences were found as before; again there was a complete separation between the autists and the normals with regard to solo behaviour, and associative behaviour (Fig. 6).

Disappointment came, however, when we sought the behaviour: catecholamine correlations found in the first sample. None of the predicted correlations were found. Worse still, no others were found either. In other words, widening the sample size led to the disappearance of *all* the behaviour: catecholamine correlations, and this naturally left us in some bewilderment.

Conclusions

Clearly, the first conclusion we must come to is that there are no one-to-one correlations between types of human behaviour (at least those we studied) and catecholamine excretion levels (perhaps also other aspects of physiology correlated with 'stress').

Table 4

Subjects studied in the second sample

Child	Normal/autistic*	Sex	Age**	Wt (kg)
Nora	N	F	81	26
Margaret	N	F	65	20
Patricia	N	F	65	19
Julie	N	F	62	17
Nina	N	F	81	21
Suzanna	N	F	61	19
Rosemary	N	F	63	24
Elizabeth	N	F	62	17
Jayne	N	F	83	23
Carol	N	F	65	22
Richard	N	M	82	24
Bob	N	M	63	20
Shaun	N	M	66	22
Barry	N	M	65	21
John	N	M	63	22
Brian	N	M	83	23
Tim	N	M	62	18
Steve	N	M	82	22
Martin	N	M	81	28
Jeremy	N	M	81	24
Cecily	A	F	125	28
Adam	A	M	120	35
Sam*	A	M	111	27
Ken*	A	M	106	22
Robin	A	M	69	15
Darrell*	A	M	135	35
Henry*	A	M	129	33
Arthur	A	M	136	25
Colin	A	M	125	25
Hubert	A	M	130	29
Terry	AS	M	101	23
Mel	AS	M	137	28
Randolph	AS	M	69	25
William	AS	M	62	23
George	AS	M	155	47
Hamilton	AS	M	118	32
Edward	AS	M	85	26
Ben	AS	M	113	42

* N = normal, A = autistic Smith, AS = autistic Springhallow, ** = age in months, * = also studied in sample I

Second, we can say that while autistic and normal children differ dramatically from each other in their behaviour patterns, physiologically they do not differ, at least not when large samples are considered together.

Nevertheless there are other ways of looking at the data, and this we have done, leading to a more productive conclusion.

The smaller sample had yielded at least *some* correlations and we, therefore, took an entirely different look at the data, considering each individual separately. As already pointed out, children (both normal and autistic) tend to show characteristic forms of behaviour and characteristic catecholamine levels. Since there is no *overall* correlation, we must conclude that individual children

have their own characteristic correlation pattern. That, however, tells us nothing in functional terms.

How, then, may catecholamines be related functionally to behaviour? We noted that the autists, behaviourally quite abnormal, were physiologically normal with regard to 'stress' hormone e.g. their stress level was under control at the physiological level. It could, therefore, be that their behaviour has undergone a radical adjustment in order to bring their stress system into a 'normal' region. This would be to regard behaviour as a 'coping' mechanism. If we assume that, for them, social interaction is physiologically stressful, then their withdrawal into themselves is a kind of 'buffering' process, keeping them out of social situations that might be overarousing physiologically and lead to rapid exhaustion.

Although our studies have not yet been adequately designed to test this idea properly, a look at individual cases in the study already made tends to confirm this idea. On a few occasions we were observing autistic children who for some reason were forced into social interaction. In one case, for example, a boy dropped a bottle of milk and was told off for it during our study period. The result in terms of his adrenaline level was dramatic — it rose exceptionally high.

This too, of course, ties in with our other studies on individuals mentioned at the outset, and the work of others relating adrenaline to *perceived* stress. But more importantly it does two things. First it supports the idea (which has been and still is challenged) that autistic children are showing a response to stress. We suggest they have been badly stressed and have responded by withdrawal. We do not conclude that the stress could have been avoided or that anyone is to blame for it — these children may even be genetically oversensitive to normal situations.

Second, we can see the general relation between behaviour and physiological levels as one in which the former serves as a kind of adaptation to the perceived environment, making sure the body systems have the best chance of normal, regular functioning (only occasionally subjecting it to insults, e.g. when drinking heavily or engaging in athletic sports). Most particularly, we use our social behaviour to regulate the nervous stress resulting from social relationships. This is a subject that needs much further study.

REFERENCES

Cannon, W. B. (1953): *Bodily Changes in Pain, Hunger, Fear and Rage.* (2nd edn.) — Branford, Boston.

Helevuo, H. (1978): *A study of catecholamine excretion and behaviour patterns in normal and autistic children.* (D. Phil. thesis.) — Oxford University, Oxford.

Levi, L. (Ed.) (1971): *Society, Stress and Disease.* — Oxford University Press, Oxford.

Mason, J. W. (1968): A review of psycho-endocrine research. — Psychosom Med. *30;* 5.

Richer, J. (1976): The social avoidance behaviour of autistic children. — Animal Behaviour, *24;* 896–906.

Tinbergen, E. A.—Tinbergen, N. (1972): Early childhood autism, an ethological approach. — Advances in Ethology. Supplement 10; Journal of Comparative Ethology.

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